2007 (2008). The Journal of Arachnology 35:546–550

SHORT COMMUNICATION

BIOLOGY OF *GALEODES CASPIUS SUBFUSCUS* (SOLIFUGAE, GALEODIDAE)

Martina Hrušková-Martišová: Institute of Botany and Zoology, Faculty of Sciences, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

Stano Pekár[1]: Institute of Botany and Zoology, Faculty of Sciences, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

Alexander Gromov: Laboratory of Entomology, Institute of Zoology, Al-Farabi 93, Akademgorodok, 480060 Almaty, Kazakhstan

ABSTRACT. This study reports on some observations on the biology of the Central Asian solifuge, *Galeodes caspius subfuscus* Birula 1937. Solifuges were active only during summer months. At other times, they were found in burrows located in sandy soils on southeast facing slopes. They were strictly nocturnal in their activity patterns. Small specimens (juveniles) were observed to forage only in the bush using a "sit-and-wait" strategy, while large specimens (subadults and adults) foraged actively only upon the ground. Their prey included various insects including Trichoptera, Coleoptera, and Ensifera. Mating behavior appeared aggressive as several females consumed males either before or after copulation. The mating is described in detail. After mating, females deposited eggs in a burrow and guarded them, presumably until hatching.

Keywords: Camel-spiders, activity, habitat preference, prey, mating, sexual cannibalism

Solifuges are one of the most important predators in arid environments (Polis & Cormick 1986). They occur across the world except for Australia (Punzo 1998a). Despite being very abundant, little attention has been paid to their biology or ecology. Extensive work has thus far only been carried out on North American eremobatids (e.g., Muma 1966a, b, 1967; Punzo 1997). European, Asian, African, and South American species have rarely been studied (Cloudsley-Thompson 1961; Junqua 1966; Wharton 1987).

One of the most common species in Central Asia is *Galeodes caspius* Birula 1890 (Galeodidae). It is one of the largest species, attaining a body size up to 7 cm, and has been described in four subspecies (Harvey 2003). Virtually no data on any aspect of their biology has been published so far. Thus, our goal was to elucidate the main aspects of biology of *Galeodes caspius subfuscus* Birula 1937 that occurs in Kazakhstan and Kyrgyzstan. Specifically, we focused on circadian activity, habitat preference, predatory behavior, prey preferences as well as mating and post-mating behavior.

The study areas were slopes and plains (43°57′53″N, 77°03′11″E) along the Illi River in Kapchagay, in the southern part of semi-desert Taukum in southeast Kazakhstan. Observations were made during 2 wk in April and 2 wk in June 2004 and 2005. In April we focused on habitat preference by investigating factors influencing the position of burrows. In June we performed nocturnal observations using UV light in order to observe their foraging activity. Also in June, adult solifuges were collected and the mating behavior was studied in a shelter. A male and a female were put in a plastic box (25 × 15 × 6 cm) after being fed with grasshoppers to satiation. The mating that followed was recorded. Mated females were brought to the laboratory in order to continue our observations on post-mating behavior. Voucher specimens are deposited in the collection of arachnids of the Institute of Botany and Zoology, Masaryk University, Brno, Czech Republic.

Habitat.—Burrows occupied by solifuges were found by turning over stones. For each burrow (n = 60) the diameter and the length of the burrow, size of solifuge, the size of the stone, type of soil, and slope were recorded. The size of the burrow increased significantly with solifuge size (linear regression, $F_{1,50}$ = 132, $P < 0.0001$). The size of stones (area) was independent of solifuge size (linear regression, P = 0.16) as it was on average 488 cm^2 (SE = 55.7). Similarly the thickness of the stone was independent of the solifuge size (linear regression, P = 0.32), it was on average 8 cm (SE = 0.55). The solifuges

[1] Corresponding author. E-mail: pekar@sci.muni.cz

Table 1.—Number of solifuges found as a function of soil type and aspect.

Soil type (n = 3)	Aspect (n = 3)		
	South	South-East	South-West
Loess	12	5	0
Sand	0	28	5
Sandloess	0	10	0

showed significant preference for a certain type of aspect (= compass direction) and soil (contingency tables, $\chi^2_4 = 40$, $P < 0.0001$, Table 1), with the majority of them (72%, $n = 60$) occurring on the SE slope. The remaining ones were found either on S (20%) or SW facing (8.3%) slopes. Many (55%) burrows were found in sandy soils, the rest in the loess and sandy loess.

Solifuges hiding in burrows had been mentioned by several authors (e.g., Cloudsley-Thompson 1977; Punzo 1998b), and solifuges living in deep burrows under stones were observed in some North American species (Muma 1967). The burrows in other *Galeodes* species were found to be up to 240 mm deep (Berland 1932) and plugged by dead leaves (Cloudsley-Thompson 1961). Similar to other solifuges (e.g., Cloudsley-Thompson 1977; Punzo 1998b), *G. caspius subfuscus* individuals use burrows while resting during the day, as a protection during molting, and for the deposition of eggs. These solifuges clearly place burrows on slopes having a southerly aspect where they are exposed to solar radiation. This is particularly important during spring months when temperature, which affects rate of development, is rather low.

Circadian activity.—In April no solifuge was seen moving on the ground either during the day or at night. By June they were active but only at night and we observed dozens of individuals ($n = 125$). Their activity started at 21:00 (sunset) and terminated at 01:00, with maximum activity at 22:00 (Table 2). Most solifuge species are nocturnal (e.g., Lawrence 1955; Punzo 1998b) like other predators in arid environments. However, large species are strictly nocturnal (Cloudsley-Thompson 1977), presumably an adaptation to avoid predators, low humidity, and heat.

Predation.—Foraging behavior of juveniles was different than that of subadult and adult solifuges. Small individuals (juveniles) hunted exclusively on the bushes ($n = 78$) using a "sit-and-wait" strategy, whereas large individuals (subadults and adults) hunted only on the ground ($n = 47$) using active prey chasing. Juvenile solifuges hung from the branches (Fig. 1) with out-stretched pedipalps that grasped flying prey such as Trichoptera. This foraging habit has not been reported for any solifuge so far. Indeed, the majority of solifuges, both juveniles and adults, search for prey on the ground (e.g., Muma 1967).

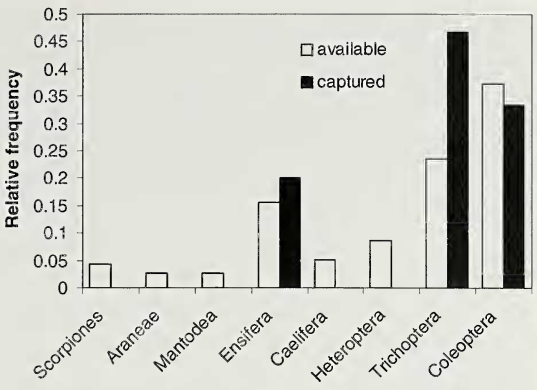


Figure 1.—Comparison of the available and captured prey by juvenile and adult specimens (pooled) of *G. caspius subfuscus*.

We investigated potential (available) prey by recording representatives of insect orders occurring in bushes and on the ground during an hour. The composition of available prey was then compared with the composition of captured prey. *Galeodes caspius subfuscus* captured mainly ($n = 15$) Trichoptera imagoes, Coleoptera larvae, and Ensifera (Fig. 2), which corresponds well to the composition of the available prey (chi-square test, $\chi^2_7 = 7.2$, $P = 0.41$). This also suggests that this solifuge is polyphagous.

Solifuges are reported to be predators with an extraordinary voracity; however, only a few field observations on solifuge foraging behavior have been made (Bolwig 1952; Muma 1966b; Wharton 1987). Apart from a few specialized termite-eating species (for example, *Chelypus hirsti* Hewitt 1915 or *Ammotrechella stimpsoni* Putnam 1883), most solifuges are generalists, feeding mainly on insects (Ensifera and Coleoptera) and arachnids (e.g., Cloudsley-Thompson 1977; Punzo 1997).

Table 2.—Number of individual solifuges active at particular times of the day in June. Hours with no activity are not included.

Hour	20:00–21:00	21:00–22:00	22:00–23:00	23:00–24:00	24:00–1:00
n	1	51	39	29	5

Figure 2.—A juvenile *G. caspius subfuscus* foraging in the bush with outstretched pedipalps.

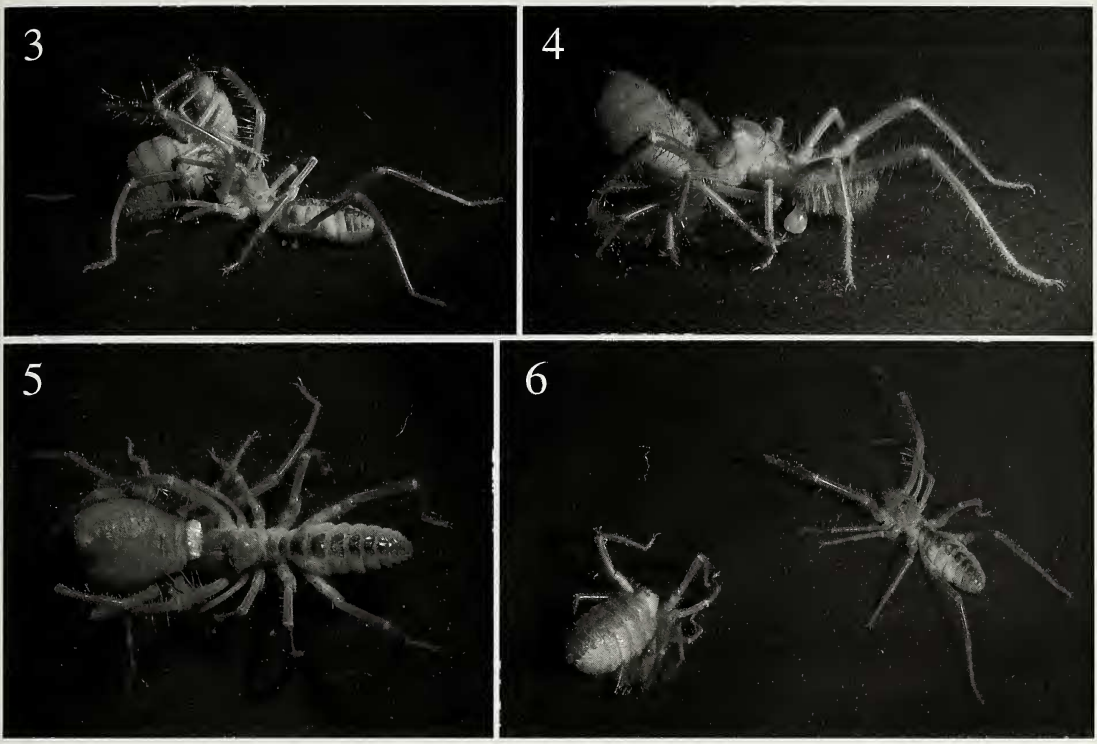
Mating.—We observed mating behavior in five pairs; in another three pairs, the male was consumed by the female prior to mating. Observed matings lasted on average 3 min 20 s and could be split into several stages. Typically, the male approached the female with raised pedipalps. The female either responded aggressively - raising her pedipalps and trying to attack the male, or became paralyzed after being touched by the male's pedipalps. If the female responded aggressively, the male suddenly fastened himself to her body using suctorial organs (Cushing et al. 2005) on pedipalps, jumped over her body and delivered a bite to the lateral region of her propeltidium. Then he began to chew her propeltidium (Fig. 3), which caused paralysis of the female. He then continued to chew the lateral and ventral parts of her abdomen close to the genital opening. During chewing, he forcibly twisted her abdomen over her propeltidium and started to chew the genital opening. While chewing, he lifted himself on all legs and released an amorphous spermatophore about 5 mm in diameter (Fig. 4). The male then grasped the spermatophore by his chelicerae and pushed it into the genital opening (Fig. 5). Immediately after the insemination, the male departed before the female awoke from the apparent paralysis (Fig. 6). After a successful copulation, males would try to copulate with a new female; however, they were unable to produce a new spermatophore. Mating behavior has been described for only a few species of solifuges so far (e.g., Amitai et al. 1962; Muma 1966a; Wharton 1987; Punzo 1997). As there are large differences between families, our knowledge about the mating of solifuges is incomplete. Within the approaching phase, striking the female with pedipalps appears to be behavior common to solpugids (Wharton 1987) and galeodids (Amitai et al. 1962; Cloudsley-Thompson 1967). It has not been seen in eremobatids (e.g., Punzo 1997). The paralyzing phase has not been observed in eremobatids (Muma 1966a), only in solpugids (Wharton 1987). There are also differences within the family. While in *G. sulfuripes* Roewer 1934 (Amitai et al. 1962) the male used only one chelicera for the insemination, in *G. granti* Pocock 1903 (Cloudsley-Thompson 1961), *Othoes saharae* Panouse 1960 (Junqua 1966), and *G. caspius subfuscus* (this paper) both chelicerae were employed.

In our study, nearly half of the males ($n = 8$) were consumed by the females either prior to or after mating. Similar cannibalism has been observed in other galeodids (e.g., Cloudsley-Thompson 1977), but not in eremobatids (Punzo 1997). We do not know exactly why the cannibalism occurred. After consuming a male, the female was able to mate a second time ($n = 3$). Sexual cannibalism in solifuges is not widely recognized as it is not mentioned in a review of cannibalism (Elgar & Crespi 1992). Our limited observations support the mistaken identity hypothesis (Elgar & Crespi 1992).

Post-mating.—In the field, we found one female guarding an egg clutch within a burrow. In the laboratory, approximately one month after mating, females laid eggs. There were on average 107 eggs in a clutch ($n = 4$). The eggs were whitish in color, spherical in shape and on average 2.8 mm in diameter. Larvae hatched after about 20 days at ~ 23° C. They were immobile and molted to the first free instar after about another 20 days.

The eggs of other solifuge species have similar shape and color to those observed in *G. caspius subfuscus*, but they were different in size and number per clutch as larger species produced larger eggs and masses (Cloudsley-Thompson 1977). *Galeodes granti* laid 32 pearly white eggs 4 mm in diameter (Cloudsley-Thompson 1961). Guarding behavior is not typical for many solifuges. Until now, guarding behavior has been observed in some galeodids (Cloudsley-Thompson 1967), solpugids (Lawrence 1949), and one eremobatid species (Punzo 1998b). Females of other eremobatids and ammotrechids simply plugged and concealed the burrow entrance after the deposition and abandoned the eggs (Muma 1967; Cloudsley-Thompson 1977).

The study was supported by NATO-Science project no. LST.CLG.980430 and the projects no. 1P05ME777, 1P06ME851 and 0021622416 of



Figures 3–6.—Mating sequence. 3. Male grasping the side of female propeltidium. 4. Male producing the spermatophore while chewing her genital opening. 5. Male inserting spermatophore into genital opening with chelicera. 6. Mating has finished, female is still in paralysis, while male is retreating.

the Ministry of Education, Youth and Sports of the Czech Republic.

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Manuscript received 20 December 2006, revised 4 June 2007.